DEC 16 1935

Volume 21 November, 1935 *Number 11*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Portable Air

The Principles of Compressor and Engine Lubrication

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

From builder to owner

MODERN EQUIPMENT MUST HAVE MODERN LUBRICATION

Builders of Diesel and gasoline driven compressor equipment have given most careful study to lubrication, and Texaco has cooperated with them. Exhaustive researches and tests are constantly being made in the Texaco laboratories to prove the qualities of lubricants under every possible condition. New processes of refining have been developed to provide new and improved lubricants that will best meet modern operating conditions. The quality and stamina of Texaco Lubricants have been proved under the toughest operating conditions.

Texaco Diesel Lubricants include Texaco Algol Oil for low temperature operation and Texaco Ursa Oils for normal and high temperature work. Both are notably free from carbon-forming elements. That means a cleaner engine, greater fuel economy, and lower maintenance costs.

Texaco Motor Oils are highly recommended for gasoline engines. These oils are made by new modern refining methods that take out a greater amount of gums, resins and carbon and provide the finest in lubricating protection you can get anywhere.

When selecting the lubricants for your compressor and power units, consult the manufacturers' recommendations. A Texaco engineer will gladly help you in choosing the oils best suited to your equipment. His wide experience should prove valuable.

THE TEXAS COMPANY

Texaco Petroleum Products

135 East 42nd Street **New York City**

ATLANTA · BOSTON · BUTTE · CHICAGO · DALLAS · DENVER · HOUSTON
LOS ANGELES · MINNEAPOLIS · NEW ORLEANS · NEW YORK · NORFOLK · SEATTLE

LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

Published by

The Texas Company, 135 East 42nd Street, New York City

Copyright 1935 by The Texas Company

Vol. XXI November, 1935 No. 11

Change of Address: In reporting change of address kindly give both old and new addresses.

"While the contents of LUBRICATION are copyrighted, other publications will be granted permission to reprint on request, provided article is quoted exactly and credit given to THE TEXAS COMPANY."

Portable Air

The Principles of Compressor and Engine Lubrication

THE ready mobility of the portable air compressor is intriguing to the casual observer as he watches the excavation activities attendant to new building construction, railway track maintenance or highway operations. It is far more than a novelty to the contractor, however, who must keep work moving regardless of weather conditions, for it has become one of the essential factors in mass handling of bulk materials. The intensity of this service requires the most careful consideration of maintenance procedure. In particular, it has brought the operator to full realization of the value of lubrication as a medium for parts protection.

The portable compressor has called for a type of design capable of functioning oftentimes on "service station lubrication" far afield from the ministrations of the lubricating engineer. One, therefore, finds the air compressor, Diesel engine, gasoline engine and other attendant parts handled and lubricated in much the same manner as the truck or tractor, exposed to a wide variety of labor and subject frequently to handling by men who have but scant knowledge of the limitations of mechanical operations and the necessity for positive lubrication.

Full appreciation of these factors, and a working knowledge of compressor and internal combustion engine lubricating requirements is most helpful in reducing operating costs. With such knowledge, both fuels and lubricants can be more intelligently selected.

COMPRESSOR DESIGN

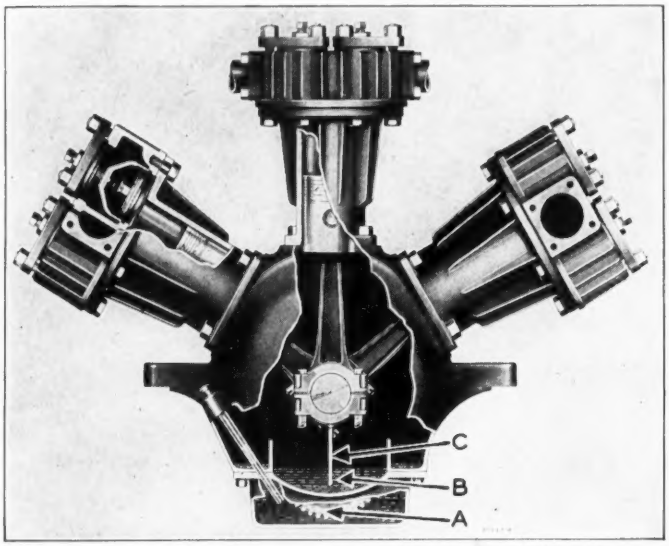
The small air or water-cooled, reciprocating compressor has been highly developed for portable service. Certain types are built with their cylinders in a straight line, others, due to space limitations, embody the principles of radial design, using either a "V" arrangement or locating both the high and low pressure cylinder in the same plane but at different angles to simulate the "W" type airplane engine. In this latter design, the vertical cylinder is the high pressure element; the two side cylinders being low pressure.

Positive compression along with adequate cooling by either air or water not only delivers more air at the required operating pressure but also reduces the temperatures of compression, thereby markedly reducing the possibility of carbon formation which might otherwise occur due to overheating and breakdown of certain types of oils.

Selection of Compressor Oil

Air compressor cylinder lubrication requires an oil which possesses certain very definite properties. It must not only lubricate effectively but at the same time it must resist decomposition when exposed to heated air, otherwise it might become a hazard due to possibility of explosion. Those properties which will indicate the ability of the oil to meet the above requirements are covered by the rela-

tive change in viscosity, the flash and fire temperatures and the tendency to form carbon deposits.



Courtesy of Ingersoll-Rand Company

Fig. 1—Cutaway view of the Ingersoll-Rand two stage, air-cooled compressor, showing at "A" the oil gear, at "B" the oil trough and at "C" the dipper pin. With this arrangement, oil is maintained at a constant level in the oil trough.

The Effect of Change in Viscosity

To understand the importance of viscosity, one must realize that the body of the oil will be subject to change in its relative fluidity with change in temperature. Due to the extent to which cylinder wall temperatures will vary, the viscosity of the oil used must therefore be given careful consideration for the degree of piston seal attainable can be judged by the indicated viscosity of the oil at operating temperatures. This in turn will affect the efficiency of compression.

Too light a bodied oil, i.e., one too low in viscosity at the operating temperatures in the cylinders might easily result in it working past the piston rings to impair the seal. Too heavy an oil would in turn tend to develop gummy matter, which would result in the piston rings becoming stuck.

While an air compressor oil should have a viscosity high enough to sustain the weight of the moving parts and form a proper seal between the piston rings and cylinder walls, it should never be so heavy as to atomize with difficulty or develop excessive internal friction within itself. Moreover, if too heavy an oil is used, the resultant film on the cylinder walls will more easily collect any dust that may be present in the air and bake on the hot surfaces to form carbon deposits. This is especially likely to happen when more oil has been used than just sufficient to lubricate the wearing surfaces or where an air cleaner is not used.

Flash and Fire Points

The extent to which flash and fire points have been stressed by some in regard to the relation to effective compressor cylinder lubrication requires analysis of their actual importance.

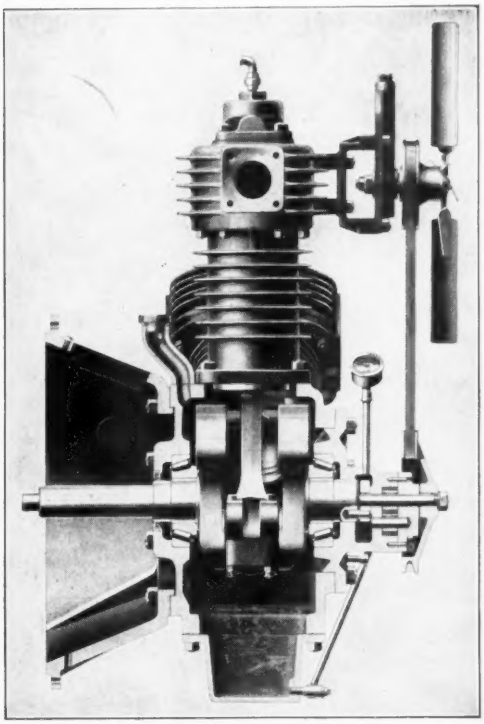
High flash and fire points have been decidedly over-emphasized in their relative importance as qualifications for air compressor lubricants. In fact, observation of the conditions under which explosions will tend to occur has indicated that the possibility of formation of deposits within the compressor or air lines requires far more consideration.

In any installation where they are present and rendered incandescent for any reason whatsoever, an explosion may occur irrespective of the flash or fire points of the lubricating oil. Otherwise the oil would have to be exposed to a temperature much higher than its laboratory flash point before combustion could take place. When we consider that the flash point will normally range in the neighborhood of 350 to 400 degrees Fahr., whereas the temperature of actual combustion would be in the neighborhood of 1100

Courtesy of Sullivan Machinery Company

Fig. 2—Top side view of the Sullivan two stage, air-cooled compressor, showing arrangement of cylinders in two banks in a true "V", which makes it possible for a baffle, directly back of the fan, to lead cooling air onto the cylinders and not between them.

degrees Fahr., one can readily appreciate that it is unwarranted to worry as to the possibility of certain compressor oils being the more ex-



Courtesy of Worthington Pump and Machinery Corporation

Fig. 3—Cutaway view of the Worthington air-cooled, two stage, portable compressor. Note application of Timken tapered roller bearings to the crankshaft.

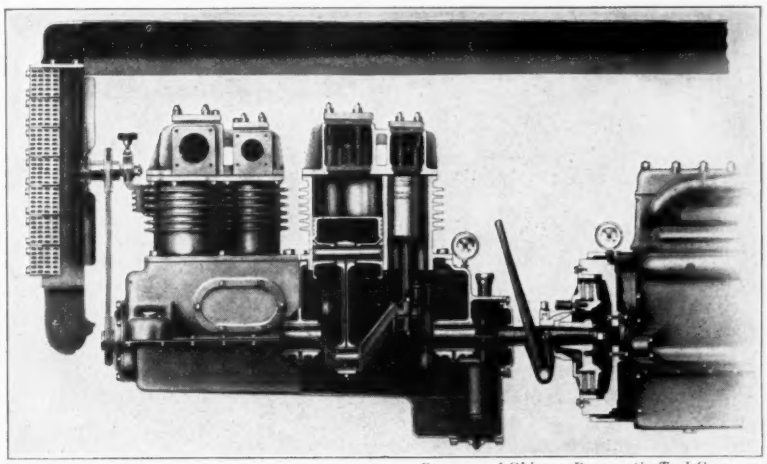
plosive, simply because their flash point is below the temperature of the discharged air. Provided that oil accumulations in the receiver are not allowed to occur, that carbon or silicious deposits are guarded against and discharge valves are maintained in proper condition to prevent air leaks no difficulty should be experienced.

It is also important to remember that cylinder walls of the portable compressor are adequately cooled and hence the temperature of the oil layer next to the walls will normally be but little above that of the walls themselves. The oil layer exposed to the heated air, however, becomes much hotter than the rest of the oil body and a portion of it may be vaporized. As oils are composite mixtures, different portions will be distilled or vaporized at different temperatures. Certain of the lighter products may pass off even at temperatures below the flash point, leaving the heavy ends dissolved in the oil next to the walls. The final result, especially where an excess of high carbon content oil is used, may be oxidation and the building up of a gummy mass which has a low vapor pressure and high distillation point. As a result the indicated carbon residue content should be studied as well as the degree of refinement of the oil.

Carbon Deposits the Result of Oil Breakdown

Breakdown or decomposition as mentioned above is in part responsible for deposits of carbon plus dirt on the valves or in the discharge lines of an air compressor. It is impossible to get away from this phenomenon for mineral lubricating oils, regardless of their base or nature will decompose to volatile products and carbon when subjected to hot air under pressure. On the other hand, the extent of this decomposition will depend on the length of time the oil is exposed to such heat. Naturally, it will also follow that with oils of the same degree of refinement the one which remains in the compressor cylinder or on the discharge valves the longest will form the greatest amount of carbon.

It is interesting to note that analysis of numerous so-called carbon deposits has proved them to consist more of dirt than of carbon, the whole being held together by gummy mat-

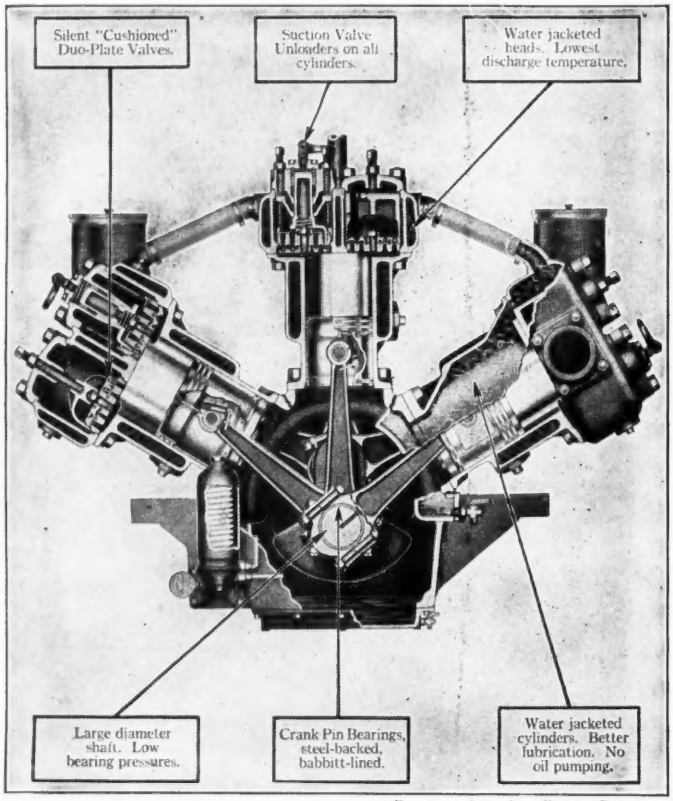


Courtesy of Chicago Pneumatic Tool Company

Fig. 4—The Chicago Pneumatic two stage, air-cooled compressor, with cylinders arranged in-line. All parts of this machine are provided for force feed lubrication, with provision to prevent oil-pumping. The intercooler, as well as the cylinders, is air-cooled in this machine.

ter from decomposed oil, especially where the latter has been unsuited to the service involved. Obviously, an oil having a wide range of distillation, high end point or too great a vis-

cosity is objectionable, inasmuch as, instead of vaporizing cleanly, it breaks down as has been mentioned above, becoming sticky and collecting dirt brought in by the air. The slower the breaking down process or the greater the volume of oil involved, the more carbon will ultimately be developed with greater possibility of subsequent trouble.


Silent "Cushioned" Duo-Plate Valves.
Suction Valve Unloaders on all cylinders.
Water jacketed heads. Lowest discharge temperature.
Large diameter shaft. Low bearing pressures.
Crank Pin Bearings, steel-backed, babbitt-lined.
Water jacketed cylinders. Better lubrication. No oil pumping.

Courtesy of Gardner-Denver Company

Fig. 5—The Gardner-Denver two stage combined air and water-cooled compressor. In this machine cylinders and heads are water-cooled, the intercooler being air-cooled. A force feed lubricating system delivers filtered oil to all operating parts.

Manner of Formation

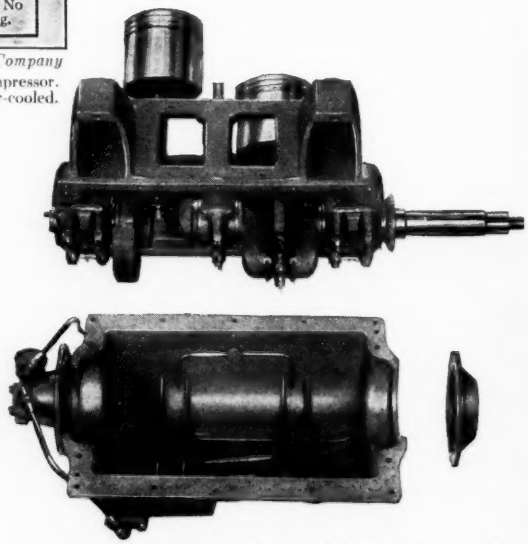
Carbon in its true form may develop in air compressor cylinders in a hard mass or it may be produced in the shape of dust and pass out with the air. In the latter case, it will often collect in pockets, elbows or on sharp edges and become mixed with dirt taken in by the air as well as with oil which has been vaporized in the cylinder and later condensed at these points.

Inasmuch as carbon is a poor conductor of heat when deposited in cylinders, it may become heated considerably above the temperature of the cylinder walls. This may ultimately be hazardous if allowed to continue. Furthermore, there will be possibility of accumulations developing on the valves and valve seats, and in the ends of the cylinders. This may cause valves to leak, frequently resulting also in cutting of the latter and scoring of the cylinders.

Where deposits of dirt, gum or carbon are allowed to collect in the valve passages and bends of piping to such an extent as to restrict the opening through which the compressed air has to pass, pressures may be produced capable of eventually causing failure and an explosion especially if any part of the system is weak. In view of the fact that pale filtered distilled oils, where properly refined, show the least tendency toward direct carbonization and the development of carbonaceous matter, they are generally accepted as best suited to air compressor service. Furthermore, any such direct carbon as may be formed through excessive use of such oils is normally of a light, fluffy nature. Carbon deposits formed from improperly refined or unsuitable oils on the other hand are often of a hard flinty nature. Any oil, however, will accumulate dust if the air is dirty and there is no provision for cleaning.

THE GASOLINE ENGINE

The four-cycle type of gasoline engine is used in portable compressor service.



Courtesy of Schramm, Incorporated

Fig. 6—Showing the cylinder arrangement, crankcase and oil pan of a Schramm vertical, straight-line type of compressor. Note in particular that the oil pan, which can be lowered for access to crankshaft and bearings, contains oil troughs and the oil pump, externally mounted, to give positive lubrication to all moving parts.

In the four-cycle engine the combustion of fuel begins with the suction stroke, wherein the piston moves downward or away from the head

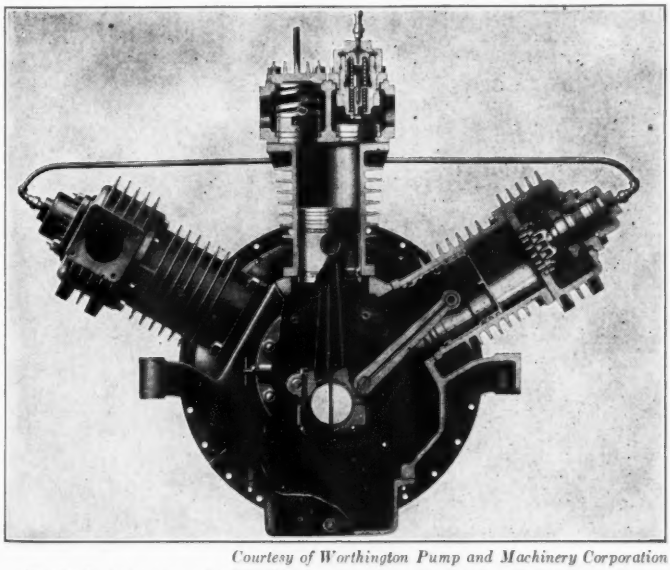
of the cylinder, to admit the fuel charge of air and gas through the inlet or admission valve which is mechanically opened.

The compression stroke follows wherein the piston travels upward or back over this path. All the valves are closed during this stroke, consequently the fuel charge enclosed within the cylinder is compressed, the pressure rising according to the compression ratio.

Work is done during the power stroke wherein the piston once again travels downward or away from the cylinder head, when the compressed fuel charge is ignited by a spark while all valves are closed. The liberation of heat caused by ignition and explosion develops the increased power necessary to drive the piston and do the necessary work.

The exhaust stroke completes the cycle wherein the piston once more travels upward towards the cylinder head, the exhaust valve opening meanwhile to permit of the complete scavenging of the cylinders by expulsion of the exhaust gases while the inlet valve is closed.

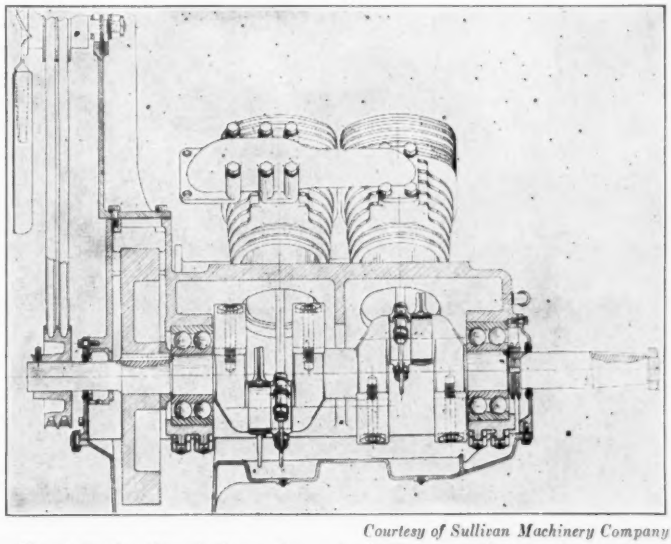
It is therefore obvious that four strokes of the piston accompanied by two revolutions of the crankshaft are necessary to complete the cycle of operations.



Courtesy of Worthington Pump and Machinery Corporation

Fig. 7—End view through a Worthington two stage, air-cooled, radial type compressor, showing connecting rod arrangement with piston and cylinder design. Note also large capacity oil reservoir in the base.

In order to maintain effective lubrication the operating factors which impose certain duties upon the oils, as well as the various lubricated parts of the engine, must be fully understood by the operators. Simplicity of design, and ready access to all parts have been accepted as fundamental requirements by the builders of the modern gasoline engine. Particular attention has been given to include completely automatic lubrication, doing away with all complications to assure positive distribution of oil to the various parts. In consequence, standardized lubricating systems are employed, differing in detail only according to the design and constructional conditions of the engine.



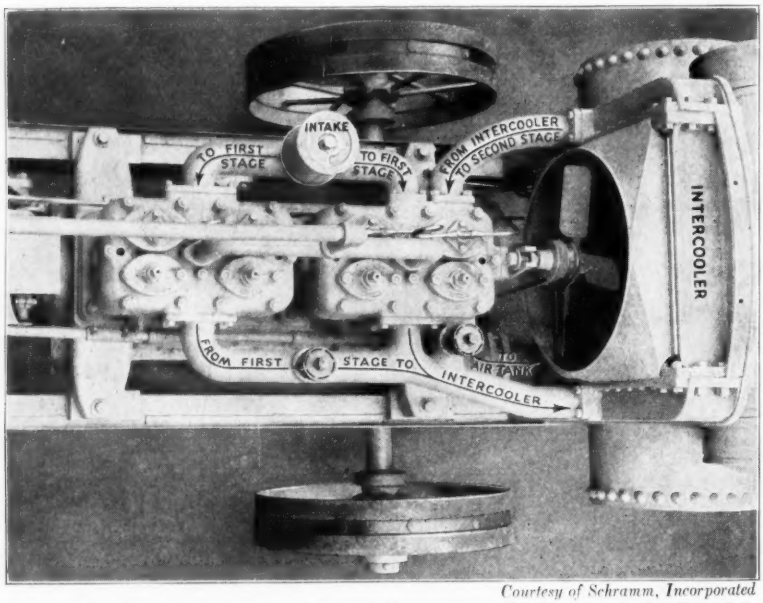
Courtesy of Sullivan Machinery Company

Fig. 8—Section through the crankcase of a Sullivan portable type air compressor, showing cylinder and connecting rod arrangement with application of ball bearings.

Gasoline engine lubrication must be positive and any oil used must be capable of developing a sufficiently tenacious lubricating film to withstand the prevailing operating pressures. The selection of lubricants for a gasoline engine should, therefore, be made strictly on the basis of quality, involving chemical characteristics to insure properly refined oils containing no impurities, and on viscosity, to insure the proper grade. Neither color nor density qualify as special properties in the selection of such an oil, although color may be significant of the degree of refinement.

Excessive friction may result from the use of an oil of either too high or too low viscosity. Too high a viscosity will give a good film but the internal friction in the oil may be excessive; conversely, if the

viscosity is too low the film may be broken. The physical characteristic, viscosity, therefore, is of supreme importance in the selection of a lubricant, as it is a measure of the ability of the oil to maintain the proper film under the existing conditions of speed, pressure, and temperature. This has been the basic thought in the preparation of the lubrication recommendation chart.



Courtesy of Schramm, Incorporated

Fig. 9—Top view of a Schramm two stage, portable compressor, showing means for handling of air to and from each stage to the intercooler.

Means of Lubrication

The means of lubrication is of course important in this regard. If positive circulation of an adequate volume of oil is practicable, and if the oil has been carefully selected as to properties which will render it capable of functioning under the prevailing operating conditions, there should be no geographic relationship between the source of the crude from which this oil has been refined and the amount of wear which may result in the normal operation of an internal combustion engine.

Where it is impossible to maintain a suitable film of oil due to ineffective means of lubrication, or road dust or other foreign matter gaining entry into the engine and becoming absorbed by the lubricating oil, wear will result between the rotating or reciprocating parts regardless of the original purity, source or characteristics of this oil.

Research has indicated that the presence of abrasives such as road dirt, etc., is responsible for about 85 per cent of all engine wear. Other causes, such as metal fatigue or vibration, are, therefore, relatively minor.

Oil filters and the filtering of the air passing through the carburetor are advantageous in reducing engine wear, for they insure maintenance of the motor oil in as nearly a state of purity as possible, provided its original refinement has been such as to insure the least amount of carbon deposit on the piston heads or valves.

Pressure circulation in turn is advantageous in that it provides for sufficient settling of the oil to insure precipitation of the heavier particles of foreign matter that may have been picked up by the oil in passage through the bearings. Furthermore, since the latter are practically flood lubricated, they will not only be washed free from accumulations of foreign matter, but also cooled to a certain extent.

A resume of a direct pressure system would show a circulating oil pump driven off the engine to deliver the oil under pressure to the main bearings and through ducts to the crank pins and piston pins. After passing through the bearings the oil drops back into the crankcase from which it is pumped to a filter or other purifying device from which the oil is again recirculated through the system.

Oil Gauge Pressure

In this connection oil pressure as shown by the gauge must also be considered. The function of this gauge is essentially to indicate that engine lubrication is being maintained. It is not a means of determining the amount of oil delivered to the various working parts, but rather the resistance to pumping involved.

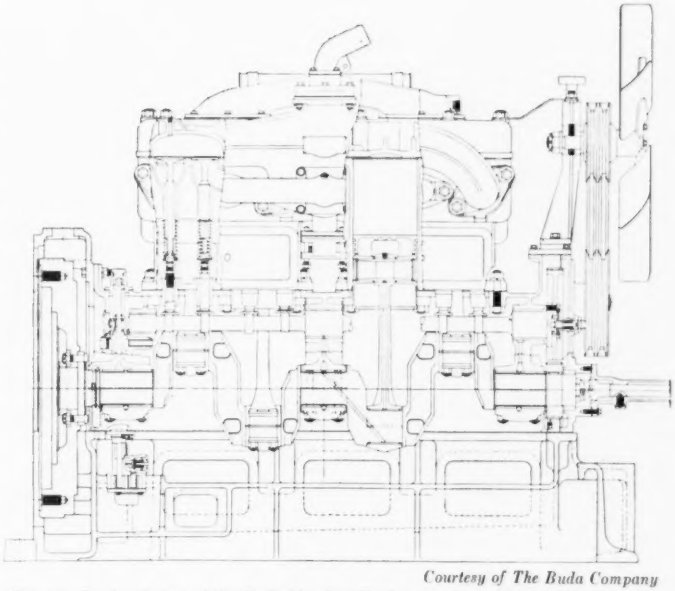
Oil gauge pressure will therefore vary according to the viscosity or relative fluidity of the oil. Oil pressure drop will frequently cause worry to some operators. It should, however, only be regarded as an indication of impaired lubrication provided pressure is lost entirely, for this may mean a broken or inoperative pump.

With the natural reduction in body or viscosity which is attendant to normal engine operation, resistance to pumping will be proportionately reduced. A certain amount of drop in pressure, especially during intensive or warm weather operation, should, therefore, be expected.

In other words, the lighter the oil, the more easily will it pump and circulate, requiring less pressure. Reduction in body or viscosity may be accomplished by heating or dilution. As a result, if the oil pressure drops too low it will be an indication that the viscosity of the oil is too low to meet the operating temperatures involved. The reason may be that originally the oil was too light, or that an excess of dilution has occurred.

The remedy is, of course, to use more care in original selection of the oil according to chart recommendations, and to operate with as lean a fuel mixture as possible. Reduced choking, the least amount of idling, and bringing an engine up to operating temperature as soon as possible after starting will all aid largely in this regard.

It will be obvious, therefore, that high or rising gauge pressure should be of far more concern, for it may be an indication of faulty lubrication due to a clogged oil line, or the oil being too sluggish and heavy to pump readily and distribute freely to the bearings, or splash to the cylinder walls, according to the type of lubricating system involved.



Courtesy of The Buda Company

Fig. 10—Sectional view of the Buda Gasoline Engine, as adapted to portable air compressor operation, showing connecting rod and crankshaft assembly with provisions for lubrication.

The Effect of Carbon Residue

Just how an excess of lubricating oil may cause abnormal carbon deposits will be of interest. Theoretically, a very small amount of oil is necessary to maintain the requisite lubricating film on the cylinder walls and serve the respective bearings; actually, however, a considerable excess of oil will be used. Where the rings give the proper degree of seal and the cylinder walls are not abnormally worn, but little of this oil should pass to the combustion chamber. If the oil level is carried too high, however, especially in oiling systems involving splash lubrication, the amount of oil on the cylinder walls may be so excessive that a certain percentage cannot help but find its way into the combustion chamber. A smoky appearance of the exhaust will frequently be an indication of this.

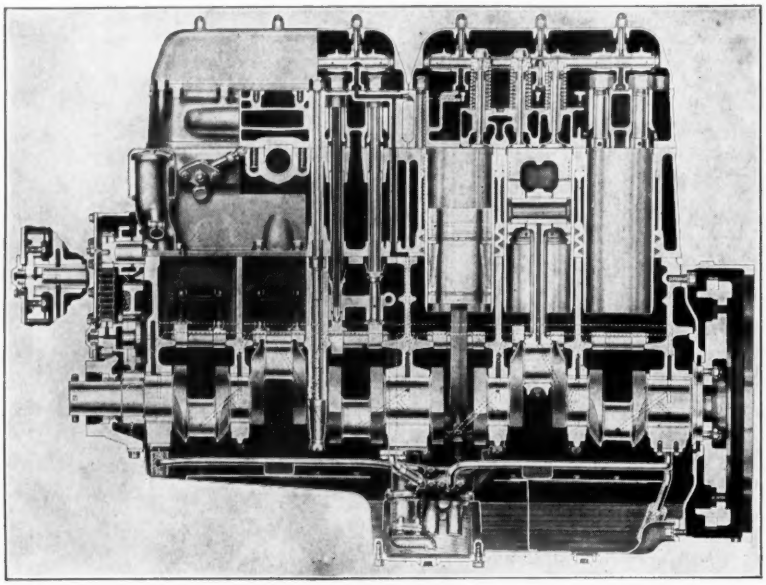
Carbon is an essential component of all petroleum products, and therefore must pass through every gasoline engine. It is only a detriment, however, in the form of soot or deposits of carbonaceous tarry matter. This may, of course, have a very decided effect upon the operation of the engine, the amount of power developed and the amount of "knocking," according to the extent to which carbon deposits are formed on the spark plugs, pistons, cylinder heads, around the rings, on valves and valve seats, and in the crankcase.

The amount of ultimate carbon residue will depend entirely upon the degree of heat present, the extent of refinement of the lubricant and the base of the crude. From particular types of crude, for example, distillates can be produced which will show an almost negligible carbon residue, 0.05 being a fair idea of the amount to be expected. The use of residual oils, however, for the purpose of blending and increasing the viscosity may easily raise the carbon residue percentage of the resultant product to one per cent or above. Lubricants of this nature will be dark green in color and comparatively opaque.

Carbon which is developed from blended oils containing residual products will, unless they have been especially refined, be harder and more abrasive than carbon from lubricants of equal viscosity, but which are wholly of a distilled nature. Hard abrasive carbon does its greatest damage as a promoter of wear on cylinder walls and bearings. Most frequently will it be developed on the upper part of the cylinder walls to be retained by the lubricating film and ultimately worked past the piston rings and into the lubricating system.

All true carbonaceous deposits in the average gasoline engine do not, of course, originate from the lubricating oil. Incomplete combustion of the gasoline or an abnormal amount of dilution of the lubricating oil will also tend to increase the amount of carbon formation in the com-

bustion chamber. In other words, the lighter the lubricant or the thinner the film on the cylinder walls, the more readily will it splash or succumb to the wiping effects of the piston. This will, of course, increase the possibility of pumping or forcing of the lubricating film up into the combustion chamber where it will be ultimately burned. The direct result is the development of more or less carbon.



Courtesy of Hercules Motor Corporation

Fig. 11—The Hercules six cylinder, Diesel type engine as adapted to portable air compressor operation. Dotted lines indicate, in part, the path followed by the oil. This lubricating system is of the double scavenging type.

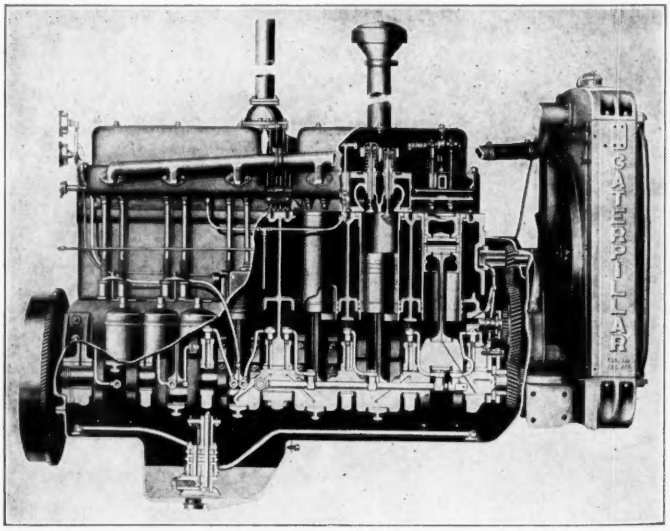
How extensively these deposits may be will, of course, depend upon the residual carbon content of the oil. Where the latter burns cleanly the amount of such deposits will be relatively small. Furthermore, if the oil is properly refined and adapted to the purpose such carbonaceous matter will be soft in appearance, low in quantity and easily removed when cleaning is necessary. Over extended periods of operation, however, carbon deposits, whatever their nature, will be bound to increase.

DIESEL AND OIL ENGINE REQUIREMENTS

Application of the Diesel or oil engine to portable compressor service has afforded an interesting alternative to the gasoline engine, to operators desirous of using heavier fuel oils where bulk oil storage facilities are available. These types of engines will enable decidedly economical operation, especially where starting can be accomplished under normal temperatures. Obviously, if a machine must start at extremely low temperatures, the gasoline engine will be preferable.

The term "Diesel or oil engine" as generally used, is applied to internal combustion engines that burn heavy liquid fuels. The distinguishing features of these engines are that the fuel vapor is not mixed with air before it is admitted to the cylinder, and no inflammable mixture of vapor and air is compressed preceding ignition.

Diesel engines compress air alone and the heat of compression is used to ignite the fuel which burns by consuming the oxygen of the air in the cylinder, the engine transforming the heat energy into work. To facilitate and accelerate the burning of a liquid fuel, it must be vaporized and intimately mixed with air immediately preceding its ignition. Both the Diesel and oil engine as designed for portable compressor service, are capable of burning practically any grade of liquid fuel from kerosine upward.



Courtesy of Caterpillar Tractor Company

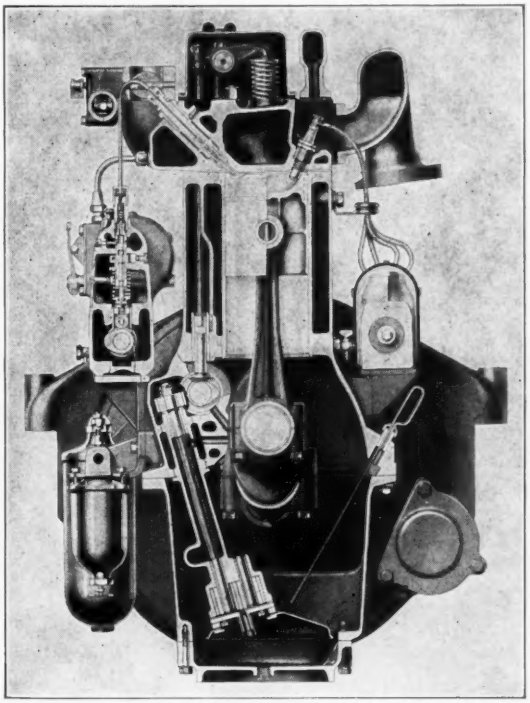
Fig. 12—The Caterpillar six cylinder Diesel engine, in longitudinal section view, showing details of construction and the pressure lubricating system.

The Lubrication Theory

A study of those factors which may affect lubrication is always of interest. Oftentimes, they are lost sight of or at least overlooked as long as the lubricating system seems to be functioning satisfactorily. Frequently, it is assumed to be efficient, while, as a matter of fact, the use of an improper lubricant may be causing serious power losses.

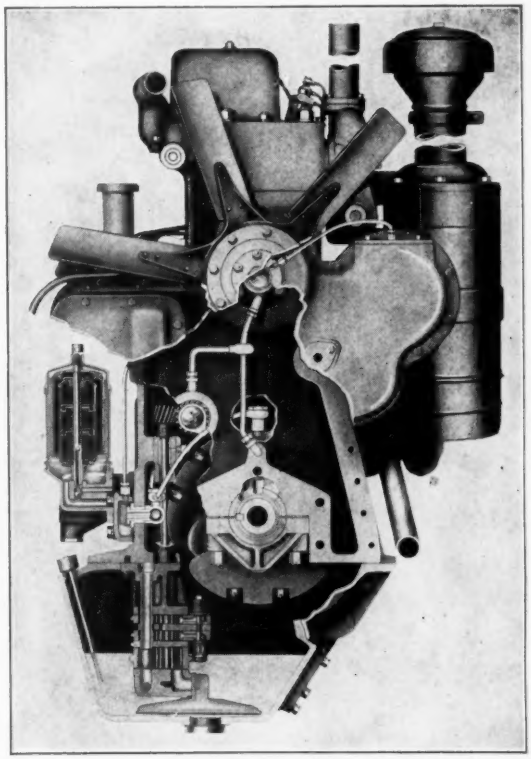
There may also be chemical or physical imperfections in the metals of the bearings or journals, or mechanical defects in the fitting of these parts that are not always evident even on close inspection. All, however, may readily cause excessive friction and correspondingly high temperatures.

All surfaces are of course more or less rough; even surfaces which are well machined and polished show, under the microscope, small projections and depressions. It is the interlocking of these minute projections which causes solid friction when two surfaces are pressed together and moved relative to one another without lubrication. This must never occur in actual operation, however, as seizure of the respective parts will occur very quickly. Hence the necessity of lubrication, whereby the lubricant, by adhering to the rubbing surfaces, forms a protective film between them, which under the prevailing conditions of speed, pressure and temperature will resist being squeezed out, and thereby keep the frictional surfaces apart.



Courtesy of Waukesha Motor Company and Ingersoll-Rand Company

Fig. 13—Sectional view thru a type "H" oil engine. This engine is of distinctive design, being a spark plug, fuel injection unit capable of operating on fuel oil. It is pressure lubricated and water-cooled.



Courtesy of Caterpillar Tractor Company

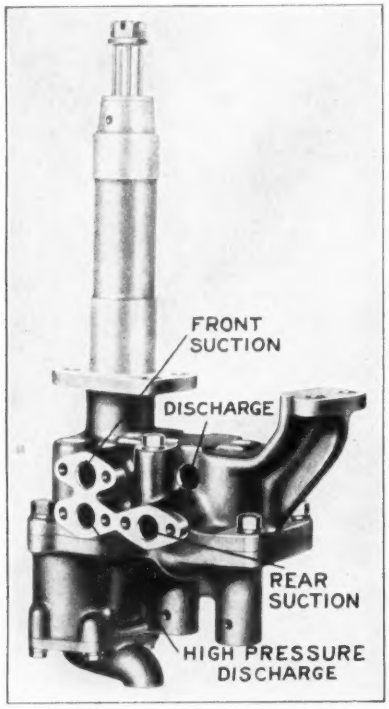
Fig. 14—End cross sectional view of the Caterpillar six cylinder Diesel engine, showing the lubricating system in considerable detail.

In perfectly lubricated bearings, the rubbing surfaces never actually touch one another and the friction is entirely fluid and contingent upon the internal resistance developed within the lubricant itself. Fluid friction, in turn, is dependent upon the speed and area of the rubbing surfaces and the viscosity of the lubricant at the working temperature of the oil film, but is independent of the pressure between surfaces, the condition of the rubbing surfaces, and the materials of which they are composed.

When an engine stands idle for any length of time, the oil films on the various working parts become more or less dissipated. This is due to static pressure and the weight of the parts which causes these films to be squeezed out, with the development of a certain amount of metallic contact. This will result in hard starting as the static coefficient of friction approaches that of solid friction. The starting effort will, of course, depend on the conditions and nature of the surfaces in contact and on the pressure between them.

As the parts begin to move, the kinetic coefficient of friction comes into play and as the

speed increases and the oil film is formed, the kinetic and solid friction decreases until perfect film formation is attained. The high values of the static coefficient easily explain the amount of power so often required to start an engine from rest.



Courtesy of Hercules Motors Corporation

Fig. 15—The lubricating system of the Hercules Diesel is of the force feed type. The oil pump, as shown above, is of large capacity and gear driven, having a double scavenging suction arrangement, which assures proper suction of oil even though the engine be inclined at an extreme angle.

It can be readily appreciated that the severe service conditions prevailing in the lubricating system of any such engine will result in breakdown of inferior or unsuitable lubricating oils. This is usually manifested by the precipitation of gummy deposits, although these are not always easily detected and the oil may still appear to be in fairly good physical condition. Gummy deposits are most dangerous when they lodge within the oil pipes leading to the bearings, or the oil ducts within the crankshaft or the connecting rods. The accumulation of such deposits may not be observed until sudden restriction or stoppage of oil to some bearing or group of bearings occurs, with resultant burned out bearings and the necessity for costly repairs.

Power Cylinder Lubrication

Efficient lubrication of the power cylinders requires continual maintenance of an oil film on the cylinder walls to afford adequate protection regardless of the grade of fuel, the completeness of combustion, the piston ring pressure, and operating temperature. Successful engine cylinder lubrication is dependent on three factors; i.e.,

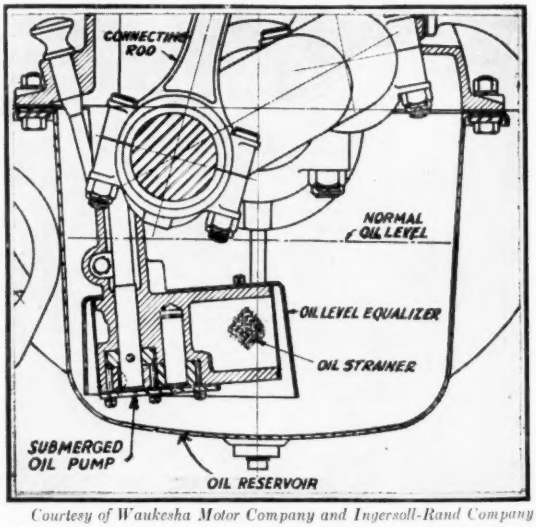
1. The use of properly refined oil.
2. Application of sufficient, though never excessive, amounts, and
3. Delivery through oil-ways so located that the piston and rings will receive the maximum of this charge.

In order to secure the most effective lubrication of engine cylinders, the oil should be delivered continually to the cylinders and pistons by some form of automatic lubrication, which will insure a charge of sufficient volume to cover the entire cylinder wall under the swabbing action of the piston.

Importance of Good Piston Seal and Oil Film

The high pressure gases above the pistons of any such engine are prevented from leaking between the piston and cylinder walls by properly fitted rings in conjunction with a suitable sealing medium in the form of a lubricating film. Although the metal surfaces of cylinders, pistons, and rings are carefully finished and accurately fitted, leakage of gases cannot be prevented unless the small openings between the wall and rings are effectively sealed by the lubricant.

Metal surfaces rubbing one over the other will generate excessive heat and produce abrasion of the materials unless the surfaces are separated and free motion permitted through the use of a suitable fluid medium. This results in metallic friction being replaced by less severe fluid friction and provides an adequate lubri-



Courtesy of Waukesha Motor Company and Ingersoll-Rand Company

Fig. 16—Oil level equalizer for the type "H" engine. The intake for lubricating oil on these units is protected against lost suction caused by low oil level or cold conditions by means of this equalizer, which consists of a bell-shaped housing surrounding the main oil intake, which compels the suction of the circulating pump to draw oil from below in an upward direction and prevents the drawing in of air.

cating film to seal the pistons properly while minimizing destructive metallic friction.

The lubricating oil film must be maintained under two distinct conditions of operation; i.e., high temperature and high pressure. The higher the temperature of the products of combustion, the hotter will be the adjacent parts, with consequent reduction in the body of the oil film separating the metal surfaces. The greater the gas pressure, the more difficult it is to maintain a lubricating film between the rubbing surfaces. The upper piston rings, especially, will be called upon to bear the brunt of these operating conditions.

Effect of Cylinder Pressure on Oil Film

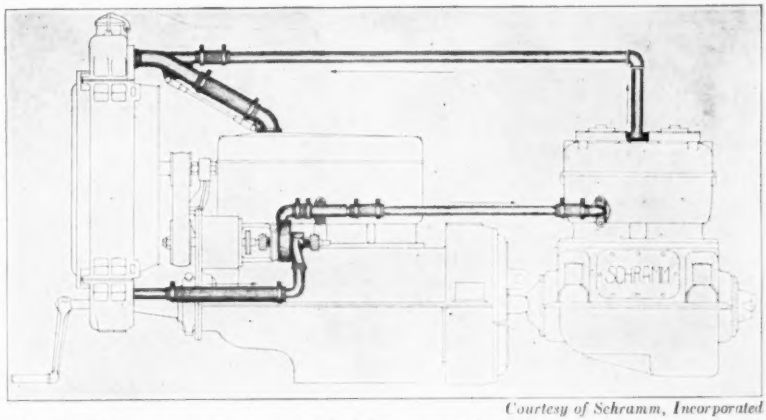
With pressures rapidly increasing during the compression stroke, until a maximum of several hundred pounds per square inch is reached above the pistons, it is the duty of the oil film to reduce leakage of the compressed air to a minimum. Otherwise there would be tendency for escape past the rings as well as past the clearance between each ring and its groove. This causes pressure to build up behind the rings. The highest pressure is, naturally, behind the uppermost ring and is nearly as great as that on the piston head itself; it decreases gradually behind each succeeding ring until it is practically negligible behind the lowest ring.

These pressures along with the natural spring of the rings will tend to force them against the cylinder wall, producing a squeezing action which the lubricating oil must support. The oil film is, therefore, depended upon to withstand the pressure of the rings, while at the same time it must effectively seal them against blowby during the compression and power strokes.

Effect of Cylinder Size on Oil Film

The influence of heat and temperature on the lubricating oil film in the engine cylinders is also dependent on the size of the cylinders. With two cylinders of somewhat different diameters but equal mean effective pressures, the products of combustion will lose their heat less rapidly during the power strokes in the cylinder having the larger dimension.

Small bore cylinders are more easily lubricated. Although the cylinder wall area increases only as the bore so that the heat conditions might not at first be considered serious for large bores, they do become more so as the size increases. This is borne out both by increased lubrication and cooling difficulties. The amount of heat liberated increases as the square of the diameter and the greatly increased heat effect is probably due to radiant dissipation of heat. This has been shown experimentally to be a very important factor in heat loss from the burning charge to the walls. Combined with the unavoidable greater thickness of cylinder liners in larger engines, the temperature difference between the cooling water and the gases in the cylinders will tend to increase. Furthermore, increased cylinder wall thickness tends to reduce the heat absorbed by the cooling water, and therefore, augments the temperature of the oil film. As the temperature of the oil film is greater with large cylinders than with small ones the former require the use of a somewhat higher viscosity oil for efficient lubrication.



Courtesy of Schramm, Incorporated

Fig 17—The two-way cooling system of the Schramm portable air compressor, wherein water serves as the cooling medium for both the engine and compressor.

Combined Effect of Temperature and Pressure

The high temperature of combustion in an engine cylinder occurs simultaneously with the high pressure. This combined action, especially under adverse conditions, will be very detrimental to the oil film which will tend to thin down; it will furthermore enhance loss of compression and excessive cylinder liner wear. This inevitably results in increased power and upkeep costs.

Under such conditions of high pressure and temperature, the lubricant must be able to spread rapidly on the cylinder walls and to replenish its own lubricating film. It must have film strength even when exposed to high combustion temperatures as well as the pressures to which it is subjected through the piston rings, and it must maintain a complete piston

seal effectively under all conditions. Cylinder liner wear is generally greatest at the combustion end of the cylinder, in the vicinity of the upper piston ring, where maximum temperatures and pressures exist. The wear decreases along the cylinder walls in proportion to the lower temperatures and pressures encountered during the power stroke.

Bearing Wear

Bearings may be classed generally under two divisions: journal bearings and thrust bearings. Journal bearings are cylindrical and the load is carried at right angles to the axis of the bearing. When the load is carried or applied in a line parallel to the axis, we have what is called a "thrust" bearing.

Effective lubrication of a cylindrical bearing may be difficult due to the fact that lubricating oils do not flow at right angles to the axis of the journal, nor parallel to the line of surface motion, but have a tendency to flow at various angles from such lines, and always toward the ends.

The evil and undesirable consequences of excessive bearing wear may be as serious as those of excessive cylinder wear, sometimes even more. It is impossible for metal surfaces under pressure, such as journals and bearings, to move in actual contact even for short periods of time without generating heat. This will quickly become excessive and eventually will injure the materials. Such surfaces therefore must be positively separated by a film of lubricating oil.

While cylinder wear, in extreme cases, leads to loss in compression and consequent loss of power, excessive wear of main bearings, for example, in addition to loss of power may also lead to fracture of the crankshaft. Furthermore, bearing troubles are not always apparent or audible. In a two-cycle, single acting engine, for instance, where the load is always in one direction, that is, downward, considerable bearing wear may have occurred without any audible signs. In contrast, in the four-cycle engine, comparatively smaller amounts of wear may be indicated by pounding, especially if this wear has occurred in the wrist pin bearings.

Amount of Lubrication Required

The quantity of oil which should be circulated through a bearing lubricating system varies widely, according to engine design and the means of lubrication. It is largely dependent upon the size and speed of the unit as well as the design of the lubricating system. The chief requirement is that the amount of oil circulated shall be considerably in excess of what is actually necessary for lubrication, to enable the volume of oil flowing through the bearings to serve as a cooling medium in addition to maintaining a film between the bearing surfaces. Properly refined lubricants will not break down under such arduous service and will readily carry the prevailing pressures, serving as well as decidedly effective cooling media. In regard to this latter, however, it must be borne in mind that heat transfer ability will vary directly as the viscosity.

Film Formation

When a shaft at rest starts to revolve, the lubricating oil adhering to the surface is drawn in between it and the bearing, to form a wedge in the pressure area, being accelerated by the pressure on the oil. The bearing serves as an effective auxiliary oil pump in this respect. If the velocity of the rotating element is low, especially if the oil is fairly heavy, it is very possible that a complete oil film may not be formed immediately. It is claimed, however, that with a velocity as low as ten feet per minute oil is drawn into the clearance space to form such a wedge. As this wedge of oil forces the shaft over, its center is raised to a position more in line with the center of the bearing, to eliminate actual metallic contact. As the velocity increases, the thickness of the oil film becomes more uniform and the center of the shaft approaches more closely the center of the bearing. If the load be increased, however, beyond the carrying ability of the oil film the clearance at the point of maximum load may be so reduced as to lead to rupture of the oil film and result in metallic friction, wear, and possible breakdown of the unit.

Printed in U. S. A. by
Edgar C. Ruwe Co., Inc.,
72 Washington St., N. Y. C.